

Studies on southern Australian abalone (genus *Haliotis*) X. Food and feeding of juveniles

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ABSTRACT

The natural diet of juvenile *Haliotis laevigata* Donovan and *Haliotis scalaris* Leach was examined at West I., South Australia. Crustose coralline algae are the principal food eaten by both species from a length of 5 to 10 mm. From 10-20 mm length the diet switches to dead seagrass blades and drift algae such as *Lobospira bicuspidata* and *Asparagopsis armata*; geniculate coralline algae also become more important with increasing length. Large brown algae such as *Ecklonia radiata*, *Sargassum* spp. and *Cystophora* spp. which dominate the habitat are avoided.

Crustose corallines are rasped from the rocky substratum whereas the drift algae lie between and under boulders where they are captured by the abalone.

From about three years of age, both abalone species occur in higher densities in deeper water where they are presumed to migrate to feed on the preferred food - algae, which are abundant there as drift.

INTRODUCTION

The need to understand the recruitment process in commercial species of abalone has focused increasing attention on the ecology of juveniles. The food and feeding of juveniles is an important aspect of niche that has been little studied, and is also of increasing relevance in mariculture. The food of newly metamorphosed abalone larvae has been examined by Garland *et al.* (1984) and the availability of food on crustose coralline algae by Lewis *et al.* (1985). Other studies of juvenile feeding of abalone are by Tomita and Tazawa (1971), Leighton (1972) and Bucher (1984).

Haliotis laevigata Donovan and *Haliotis scalaris* Leach recruit onto crustose coralline algae on and under boulders at West I. and remain in the same micro-habitat for several years (Shepherd and Turner 1985, Shepherd in prep). Subsequently these abalone species move to less cryptic sites where they feed on drift algae (Shepherd 1973).

In this paper we describe the food eaten by juveniles of these abalone species at the study site at West I., South Australia (35° 37'S: 138° 35'E) where the earlier studies on their recruitment have been done (Shepherd 1973). A map of the site is given by Kangas and Shepherd (1984).

MATERIALS AND METHODS

The north shore of West I. is a boulder slope with rounded boulders mostly of 30–40 cm greater diameter and 20–30 cm lesser diameter from 0.5 to 5 m depth. Sixty-one *H. laevigata* and 114 *H. scalaris* from 4–70 mm long were taken in October and November 1986 during morning dives. Each abalone was dissected and the contents of the digestive tract spread out onto a slide under a coverslip and examined under a binocular microscope (x20). A grid with 25 intersections was placed under the slide and the alga at each intersection was identified to species or species-group to give the relative abundance by volume of food algae. Algae were categorised as crustose corallines, filamentous algae, green, brown or red macro-algae and seagrass according to the functional group approach previously used at the site for other molluscan herbivores (Steneck and Watling 1982, Kangas and Shepherd 1984). The presence of crustose calcareous material in the gut contents was tested with dilute HCl. For macro-algae and seagrass it was possible in most cases to identify the taxon to species.

Densities of *H. laevigata* and *H. scalaris* were estimated by counting and measuring all individuals *in situ* in 36 to 40, 0.25m² quadrats placed haphazardly at 3, 4 and 5 m depths on the boulder slope at the study sites. Individuals were then aged by using the age-length curve derived for each species (Shepherd 1988, Shepherd *et al.* 1988). Drift algae were collected during the period at the same depths by qualitative and quantitative methods; the former covered the whole study site and were used to calculate the relative abundances of algal species with depth, and the latter (five replicates of 0.25 m² at each depth interval) to determine absolute abundances of algal drift. Ivlev's (1961) electivity index (E) was calculated with the following formula:

$$E = \frac{r - p}{r + p}$$

where *r* = the relative abundance of a prey item in the gut and *p* = the relative abundance of the same item in the habitat. A positive value indicates preference and a negative value avoidance. The index ranges from -1 to +1.

RESULTS

The proportional abundance of algal or seagrass species groups in the digestive tract of *H. laevigata* and *H. scalaris* grouped in 10 mm size classes is shown in Fig. 1. No individual < 5 mm long was found to have macro-algae or calcareous fragments of crustose corallines in the gut. At 5–10 mm length the diet of both species is largely calcareous fragments of crustose coralline algae. From 10–22 mm length the abalone switch increasingly to a diet of erect algae and by 25–30 mm length crustose corallines are of little importance as food. From about 25–70 mm changes in the diet are minor for both abalone species. Comparison of the kite diagrams in Fig. 1 shows high similarity in the diet between abalone species, except that *H. laevigata* to a length of 20 mm takes relatively more crustose coralline algae.

The seagrasses eaten (Fig. 1) are mainly dead blades of *Heterozostera tasmanica*, and occasionally *Posidonia sinuosa* or *Amphibolis antarctica*. Green macro-algae eaten are mostly *Caulerpa brownii*, brown macro-algae mostly *Lobospira bicuspidata*, with a little *Pachydictyon paniculatum*, and red macro-algae mostly *Asparagopsis armata* with small amounts of *Plocamium* spp. 'Filamentous algae' are polyphyletic and include ectocarpoid species and *Polysiphonia* sp. Geniculate corallines are mostly *Halitilton roseum*, with lesser amounts of *Amphiroa anceps*, *Cheilosporum elegans* and *Jania* sp. Crustose corallines were not identified.

The mean relative percentage composition of drift algae at 3–5 m depth at the study site (Fig. 2) shows that, at the time of the study, red algae (mostly *Asparagopsis armata*) and species of brown macro-algae were the most common drift algae. The attached algal flora in the habitat is an upper

stratum of *Ecklonia radiata* and *Cystophora* spp. and a middle stratum largely of geniculate (erect) corallines (see also Kangas and Shepherd 1984).

Electivity indices were calculated for the 5 groups of drift algae or seagrass consumed using the average proportions of each group consumed by each abalone species over the length range 20-70 mm at 4-5 m depth. The results (Fig. 2) show that the large brown macro-algae (*Ecklonia*, *Cystophora* spp. and *Sargassum* sp.) and to a less extent seagrass are avoided, red algae (both fleshy species and geniculate corallines) are taken more or less in proportion to their abundance, and *Lobospira*, a smaller brown alga, is strongly favoured.

The vertical distribution with depth of successive age classes of *H. scalaris* and *H. laevigata* (Fig. 3) shows that whereas densities of 0+ to 2+ age classes differ little over the depth range examined, the 3+ and older age classes of both species are in higher densities at 4 and 5 m depths.

DISCUSSION

The diet of individuals < 5 mm long could not be investigated by the methods used. However Garland *et al.* (1985) and Norman-Boudreau *et al.* (1986) have shown that abalone in the length range of 0.5 - 2.5 mm scrape the surface of crustose corallines and rasp the cuticle, consuming both epibiota (Lewis *et al.* 1985) and part of the epithelium. This study shows that from a size of about 5 mm the abalone radula must be able to penetrate more deeply and remove crustose material. Padilla (1985) demonstrated, contrary to earlier hypotheses (e.g. Steneck and Watling 1982), that less force is required by the radula to remove crustose coralline algae than macro-algae. Thus, until a length of at least 10 mm crustose coralline algae and their epibiota are the main source of food of these abalone and so provide a basis for their coralline habitat dependence earlier observed by Shepherd (1973), and Shepherd & Turner (1985).

The food algae eaten by these abalone could be obtained by rasping the rock surface or by catching drift algae. Of the 7 categories of food eaten (Fig. 1) only crustose corallines can be unambiguously concluded to have been taken by rasping. Crustose corallines are epiphytic on *Posidonia* and *Amphibolis* leaves, but the amounts of these seagrasses taken are negligible, and would at best account for only a small fraction of the coralline algae in the gut. Filamentous algae are variously epilithic or epiphytic on drift seagrass, and could be taken by either mode of feeding. The remaining categories of food are only present as detrital drift.

Neither species of abalone have ever been observed to emerge at night on the upper surfaces of boulders, or to feed on or under boulders by day. However, we have observed while diving during a moderate swell that juveniles adopt the feeding posture (elevated shell and extended foot) described by Shepherd (1973) for adult abalone, apparently preferring to catch passively rather than search actively for food. Hence we conclude that at this site both abalone species from a length of 10-20 mm, feed largely on drift algae trapped between or under boulders. The dependence of both abalone species on drift algae may explain why their diets are nearly identical in species composition.

This study does not address the question of possible bias due to the effects of differential digestion of algae. Because coralline algae and seagrass may remain identifiable in the gut for a longer time than, for example, small pieces of filamentous algae, our results may under-estimate the importance of the latter. However, we sought to minimise such bias by ensuring that all collections were taken in morning dives.

A mixed algal diet in which corallines and red algae are important has been reported elsewhere. Bucher (1984) found that juvenile *H. rubra* fed and grew more rapidly on a diet of red algae than on either *Ecklonia* or *Sargassum*. Tomita and Tazawa (1971) found that *Haliotis discus hannai* in its first year ate corallines and the seagrass *Phyllospadix*, and in its second year a mixed diet of seagrass, *Dictyota* and numerous red algae. *H. laevigata* reaches a length of about 20 mm in one year, and *H. scalaris* about 14 mm (Shepherd *et al.* 1985, Shepherd, 1988) so that their shift in diet, as for *H. discus hannai*, occurs at about one year of age. An important difference, however, is that *H. discus hannai* also feeds on considerable amounts of animal matter in its first year.

The factors determining food selection are poorly known. Both chemical attractants and deterrents have been identified in algae (Harada and Kawasaki 1982, Harada *et al.* 1984, Steinberg 1984, 1985) but the role of each remains uncertain. The feeding rate of adult *H. laevigata* on the various available brown algae at West I. is inversely correlated with the phenolic levels of the species concerned (Shepherd and Steinberg in prep.) suggesting that the amount of phenolics in brown algae may be of importance in determining algal preferences.

The differential abundances of age classes of both abalone species over the depth range examined suggest either that animals migrate to deeper water with increasing age or that differential mortality or settlement has occurred. While these last two possibilities cannot be excluded, the most likely explanation is that older individuals move toward the sand-line at 4.5 to 5 m depth; here the preferred drift food, *Lobospira*, a brown alga, *Asparagopsis* and other red algae, are in high abundance. Current experiments are testing this hypothesis.

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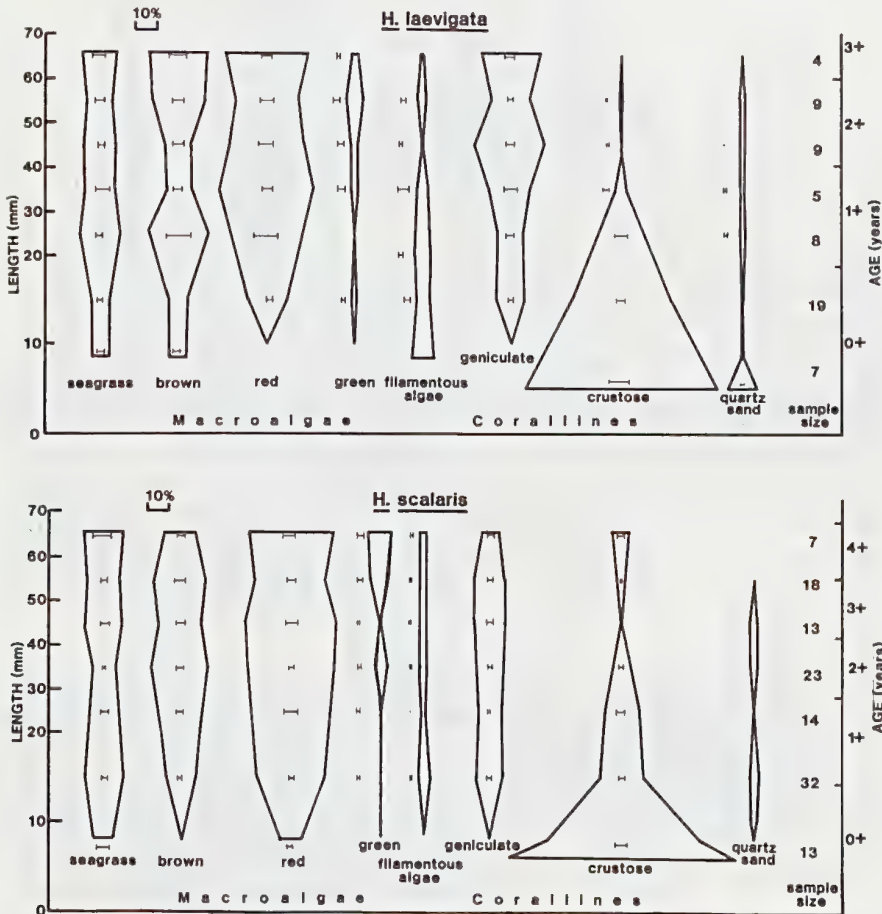


FIGURE 1 Proportional abundance of species groups in the digestive tract of (a) *H. laevigata* and (b) *H. scalaris* from 5-70 mm long. Horizontal bars give the standard errors for each size class. Note that the vertical scale from 0-20 mm length is exaggerated to show detail. The approximate age-class is shown on the right vertical scale.

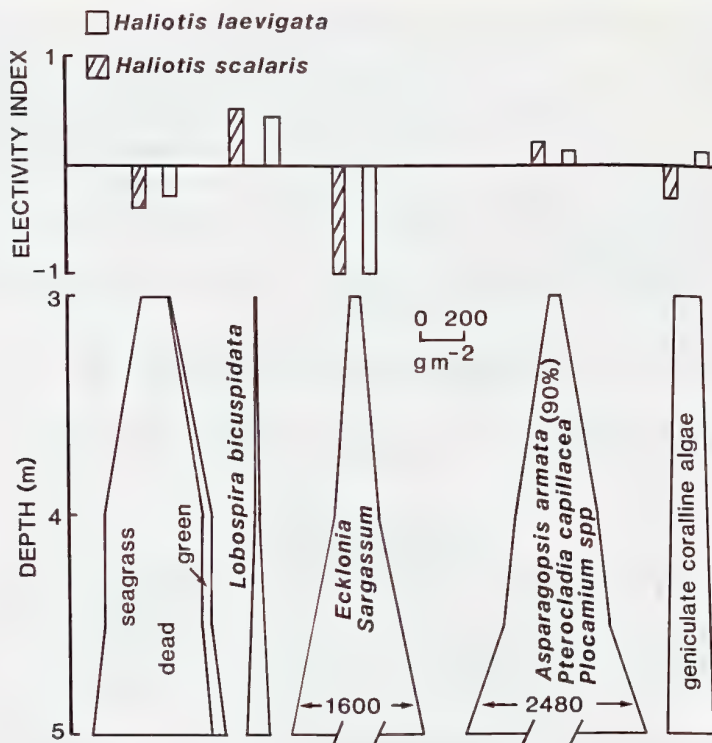


FIGURE 2 Distribution with depth of 5 categories of drift algae trapped between and under boulders, and Ivlev's electivity index values for each group.

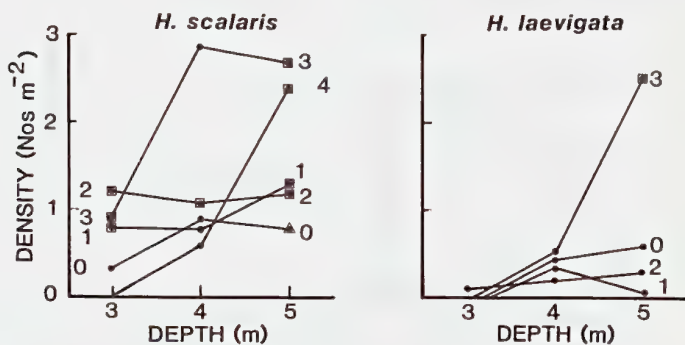


FIGURE 3 Distribution of density of five age classes of *H. scalaris* and four age classes of *H. laevigata* at the study site at West I. Standard errors are shown by symbols: 0.40 — 0.60 — squares; 0.25 — 0.40 — triangles; <0.25 — circles.